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PLASMA TREATMENT METHOD AND DEVICE

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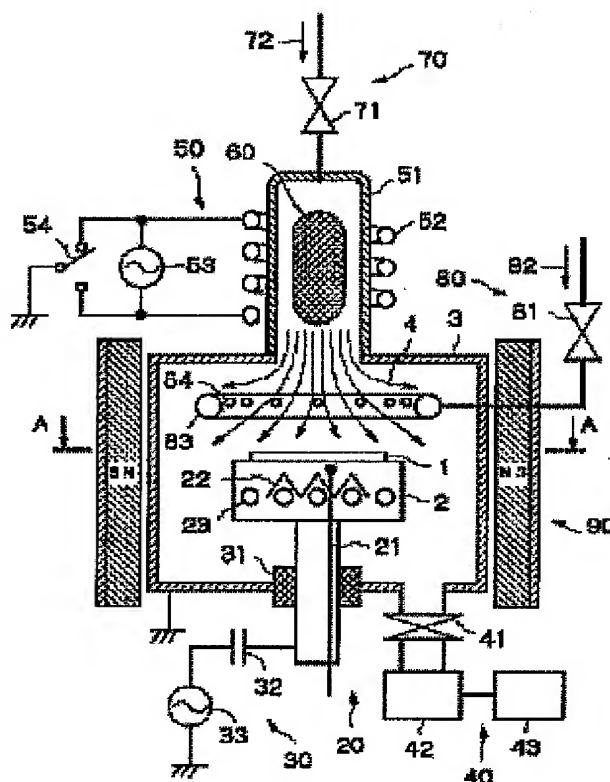
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Abstract of JP6280027

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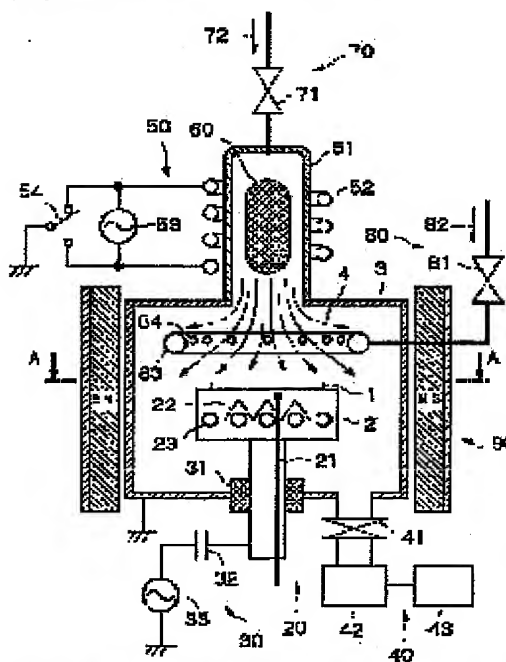
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(54) PLASMA TREATMENT METHOD AND DEVICE



(57)Abstract:

PURPOSE: To enable a substrate treatment of a large area at a high speed by introducing the neutral active species generated by high-temp. nonequil. plasma into a treating chamber where a multicusp magnetic field is formed.

CONSTITUTION: Gaseous oxygen is introduced at 200sccm flow rate into a discharge tube 51 and gaseous silane is introduced at 100sccm flow rate into the treating chamber 3. The pressure in the treating chamber 3 is maintained at 8×10^{-3} Torr. The high-temp. nonequil. plasma 60 is generated in the discharge tube 51 and oxygen atoms as the neutral active species are formed. The multicusp magnetic field is formed in the treating chamber 3 by a magnetic field generating mechanism 90. Electric power of 1500W is outputted from a high-frequency power source 33 and a bias voltage is impressed to a substrate holder 2. The substrate 1 is heated to 150°C. An SiO₂ film is deposited on a large-area silicon wafer of 10-inch diameter to obtain $2\mu\text{m} \pm 3\%$ film thickness distribution. The inside wall surface of the treating chamber 3 is coated with a fluororesin to prevent the decrease in the neutral active species.

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CLAIMS**[Claim(s)]**

[Claim 1] The plasma generating room which generates neutral active species, and the processing room which adjoined the plasma generating room and has been arranged, The exhaustor style which exhausts to a vacuum the substrate electrode holder which is installed in the processing interior of a room, and holds a processed substrate, and a plasma generating room and the processing interior of a room, In the plasma treatment approach of processing a substrate using plasma treatment equipment equipped with the gas installation device which introduces a gas required for the surface treatment of a processed substrate at least into one side of a plasma generating room and a processing room Generate elevated-temperature nonequilibrium plasma at said plasma generating room, and neutral active species is generated by activating a gas by this elevated-temperature nonequilibrium plasma. The plasma treatment approach characterized by processing a substrate by neutral active species where the plasma of the processing indoor section is separated from the wall surface of a processing room by the multi-cusp field which introduced this neutral active species into the processing room, and was formed in the interior of a processing room.

[Claim 2] The plasma treatment approach according to claim 1 characterized by introducing the 2nd gas required for the surface treatment of a substrate into a processing room, and processing a substrate while introducing the 1st gas required for the surface treatment of a substrate into a plasma room, passing the inside of elevated-temperature nonequilibrium plasma for this 1st gas and generating neutral active species.

[Claim 3] The plasma generating room which generates neutral active species, and the processing room which adjoined the plasma generating room and has been arranged, The exhaustor style which exhausts to a vacuum the substrate electrode holder which is installed in the processing interior of a room, and holds a processed substrate, and a plasma generating room and the processing interior of a room, In plasma treatment equipment equipped with the gas installation device which introduces a gas required for the surface treatment of a processed substrate at least into one side of a plasma generating room and a processing room, while forming a multi-cusp field in the interior of a processing room Plasma treatment equipment characterized by having covered wall surfaces other than near the spinode of a multi-cusp field by the neutral active species reflective member among the internal surfaces of a processing room, and changing the quality of the material of this neutral active species reflective member with the quality of the material of a processing room configuration member.

[Claim 4] The quality of the material of said neutral active species reflective member is plasma treatment equipment according to claim 3 characterized by being an oxide, a fluororesin, or a silicon compound.

DETAILED DESCRIPTION**[Detailed Description of the Invention]****[0001]**

[Industrial Application] This invention relates to the plasma treatment approach and equipment which deposit the film on a substrate, etch the film on a substrate, or reform the film on a substrate using the plasma. The plasma treatment approach of this invention activates a gas with the plasma, and is related to fields, such as generating various kinds of film (the insulator film, a protective coat, the semi-conductor film, metal membrane, etc.) used for a sensor, an optic, a sound product, a semiconductor device, etc. using this, etching these film, performing surface cleaning and surface treatment of a processed material, and performing surface hardening of a cutter or a cutting tool.

[0002]

[Description of the Prior Art] By activating a gas by the discharge plasma and making the quality of the specified substance deposit on a substrate front face using this active species, it thin-film-izes or progress rapid in recent years is shown from advantages, like it becomes possible for the approach which has processed etching, surface

treatment, etc. enough and is carried out it being able to process at low temperature and to process [which are not in the former]. Although active species means an isolation kind (radical), an excitation kind, an electron, ion, or such mixture, especially this invention is related to the art which used neutral active species before long. Neutral active species means a neutral isolation kind and a neutral excitation kind electrically. An isolation kind points out activity-the atom or molecule isolated from the molecule by which the basis was stabilized, and is in a ground state in principle. An excitation kind will be in an activity-condition when the atom or the molecule moved from the ground state to the excitation state.

[0003] By the way, in fields, such as a sensor, and an optic, especially a semiconductor device, homogeneity and high-speed surface treatment are called for by the large area. For this reason, the uniform high density plasma is produced by the large area, and the equipment which can perform surface treatment is called for, controlling active species. On the other hand, in the surface treatment aiming at hardening of a cutter, a cutting tool, etc., the need of performing production of the diamond-like film or BN film at high speed has arisen. For this reason, development of the equipment which installs a substrate in the location where the concentration of active species is high, and performs high-speed surface treatment is desired.

[0004] As invention which realized the good surface treatment process at such a high speed, there are some which were indicated by JP,4-71575,B, JP,62-227089,A, and JP,63-166971,A. It is possible to perform very good surface treatment as these invention is based on application of an applicant for this patent and it was indicated by the specification. Among these, the plasma treatment equipment indicated by JP,4-71575,B is J.Vac.Sci.Technol.A4 (3) (1986). It is important as thin film production equipment for semiconductor devices as indicated by p.475-479. In addition, although the vocabulary the "LTE plasma" comes out in said specification of an official report of three affairs, this is the same as the "elevated-temperature nonequilibrium plasma" in this application specification.

[0005] In production of recent years, for example, a semiconductor device, wafer size is becoming still larger. Moreover, the more large-sized display has been called for also in display relation. Thus, since the surface area which performs surface treatment spread, and since surface treatment high-speed about these is also required, it is uniform much more and the high density plasma production technique corresponding to a large area is searched for.

[0006] By the way, the thing using a multi-cusp field is known as a technique which carries out uniform surface preparation by the large area. For example, what forms a multi-cusp field in a plasma generating room, the thing which forms a multi-cusp field in the path or the processing room itself from a plasma generating room to a processing room are known (for example, JP,63-192229,A, JP,2-17636,A, JP,2-222532,A).

[0007]

[Problem(s) to be Solved by the Invention] It is well-known from above-mentioned JP,4-71575,B etc. to generate a lot of active species using elevated-temperature nonequilibrium plasma, and to process a substrate using this. Moreover, it is also well-known by confining the plasma in homogeneity using a multi-cusp field to process the substrate of a large area to homogeneity from above-mentioned JP,63-192229,A etc. However, with the conventional plasma treatment equipment using a multi-cusp field, the plasma is confined in homogeneity using a multi-cusp field, and a substrate is processed using charged particles, such as an electron inside the plasma, and ion. On the other hand, equipment for realizing processing of a high speed and a large area is desired about the substrate processing by neutral active species.

[0008] Therefore, the purpose of this invention offers the plasma treatment approach and equipment which enabled substrate processing of a high speed and a large area using neutral active species.

[0009]

[Means for Solving the Problem and its Function] The processing room which the 1st invention adjoined the plasma generating room which generates neutral active species, and the plasma generating room, and has been arranged, The exhaustor style which exhausts to a vacuum the substrate electrode holder which is installed in the processing interior of a room, and holds a processed substrate, and a plasma generating room and the processing interior of a room, In the plasma treatment approach of processing a substrate using plasma treatment equipment equipped with the gas installation device which introduces a gas required for the surface treatment of a processed substrate at least into one side of a plasma generating room and a processing room Generate elevated-temperature nonequilibrium plasma at said plasma generating room, and neutral active species is generated by activating a gas by this elevated-temperature nonequilibrium plasma. This neutral active species is introduced into a processing room, it is in the condition which separated the plasma of the processing indoor section from the wall surface of a processing room by the multi-cusp field formed in the interior of a processing room, and a substrate is processed by

neutral active species. In addition, in this specification, a "substrate" means the object which carries out plasma treatment, and the configuration of not only a thin tabular thing but arbitration is included.

[0010] By this plasma treatment approach, a lot of neutral active species are generable by using elevated-temperature nonequilibrium plasma first as compared with the usual plasma. And this neutral active species is led to the processing room in which the multi-cusp field was formed, and a substrate is processed. By the way, although a multi-cusp field affects a motion of a charged particle, it does not have direct effect on the behavior of neutral active species. In this invention, in order to make it not bring the plasma of the processing interior of a room close to the internal surface of a processing room, the multi-cusp field is used. Since this invention uses neutral active species for substrate processing positively, it is important for it to make it a lot of neutral active species generated in elevated-temperature nonequilibrium plasma not decrease vainly in the processing interior of a room. Although neutral active species is neutrality electrically therefore, it cannot be shut up near the center of the processing interior of a room depending on a magnetic field. Therefore, neutral active species will collide with the internal surface of a processing room in a low pressure field especially at *****. When neutral active species collides with the internal surface of a processing room, an active state will be lost depending on the quality of the material of an internal surface. Then, even if neutral active species collides by devising the quality of the material of the internal surface of a processing room, it is desirable to make it neutral active species return to the interior of a processing room as much as possible with an active state. However, if the internal surface of a processing room is exposed to the plasma, the width of face of selection of the quality of the material of an internal surface will be restricted, and it will become impossible to use an effective neutral active species reflective member. Then, it is made for the plasma of the processing interior of a room to separate from the internal surface of a processing room, and it enables it to choose the optimal neutral active species reflective member by this by using a multi-cusp field in this invention.

[0011] Rhine-like a cusp field, or a ring-like cusp field or both combination is sufficient as the multi-cusp field in this invention, and any cusp field can be used for it.

[0012] The semantics of the elevated-temperature nonequilibrium plasma in this invention is the same as the "LTE plasma" indicated by JP,4-72575,B by application of an applicant for this patent. Elevated-temperature nonequilibrium plasma can generate a lot of active species as compared with the usual glow discharge plasma, and many neutral active species are contained in it as indicated by this official report. In this invention, these neutral active species of a lot of are positively used for substrate processing. By the way, as long as electrons, ion, etc. other than neutral active species do not eliminate participating in substrate processing and, as for this invention, have played the role with neutral active species important for substrate processing, other charged particles may participate in substrate processing.

[0013] In the 1st invention, it introduces the 2nd gas required for the surface treatment of a substrate into a processing room, and processes a substrate while the 2nd invention introduces the 1st gas required for the surface treatment of a substrate into a plasma room, passes the inside of elevated-temperature nonequilibrium plasma for this 1st gas and generates neutral active species.

[0014] The processing room which the 3rd invention adjoined the plasma generating room which generates neutral active species, and the plasma generating room, and has been arranged, The exhaustor style which exhausts to a vacuum the substrate electrode holder which is installed in the processing interior of a room, and holds a processed substrate, and a plasma generating room and the processing interior of a room, In plasma treatment equipment equipped with the gas installation device which introduces a gas required for the surface treatment of a processed substrate at least into one side of a plasma generating room and a processing room, while forming a multi-cusp field in the interior of a processing room Wall surfaces other than near the spinode of a multi-cusp field are covered by the neutral active species reflective member among the internal surfaces of a processing room, and the quality of the material of this neutral active species reflective member is changed with the quality of the material of a processing room configuration member.

[0015] This invention covered the internal surface of a processing room by the neutral active species reflective member, thereby, reflected neutral active species by the neutral active species reflective member as much as possible with the active state, and has prevented reduction of neutral active species. The multi-cusp field has prevented trying for the plasma of the processing indoor section not to approach a processing indoor wall surface, and a neutral active species reflective member being exposed to the plasma by this, a neutral active species reflective member's receiving a damage, or the inconvenient matter dispersing in substrate processing in the processing interior of a room. In addition, it is better not to arrange a neutral active species reflective member near

[this] spinode, since the plasma of the processing interior of a room can approach the internal surface of a processing room near the spinode of a multi-cusp field. The internal surface of a processing room may be coated with a neutral active species reflective member, the internal surface of a processing room may be approached and it may arrange a member separate from a processing room.

[0016] Since it becomes impossible for reflecting while this neutral active species had maintained the active state to almost expect when neutral active species collides with a metal wall surface, as for the internal surface of a processing room, it is desirable to cover with the quality of the materials other than a metal. Then, the 4th invention uses the oxide, the fluororesin, or the silicon compound as the quality of the material of the neutral active species reflective member in the 3rd invention. As an oxide, quartz glass, an alumina (aluminum $2O_3$), Pyrex (trademark) glass, etc. can be used. As a fluororesin, poly tetrafluoroethylene is excellent in chemical stability and high temperature oxidation stability, and the most desirable. SiN and SiC can be used as a silicon compound. As for the quality of the material of a neutral active species reflective member, it is desirable to choose according to the class of neutral active species to be used.

[0017]

[Example] Drawing 1 is the transverse-plane sectional view of an example of the equipment for enforcing the plasma treatment approach of this invention. This plasma treatment equipment mainly consists of the processing room 3, the substrate electrode holder 2 of that interior, the potential controlling mechanism 30 for controlling the potential of this substrate electrode holder 2, the exhaustor style 40, the elevated-temperature nonequilibrium plasma developmental mechanics 50, the 1st gas installation device 70, the 2nd gas installation device 80, and multi-cusp field developmental mechanics 90. Hereafter, the structure of each part is explained to a detail.

[0018] The substrate electrode holder 2 is in the processing room 3, and the substrate 1 which performs surface treatment on this substrate electrode holder 2 is held. The processing room 3 is a product made from austenitic stainless steel, a bore is about 45cm and height is 30cm. The diameter of the substrate electrode holder 2 is about 30cm.

[0019] The temperature-control device 20 is formed in the substrate electrode holder 2. A thermocouple 21 measures the temperature of the substrate electrode holder 2. The substrate electrode holder 2 is cooled by the cooling medium which is heated at the heater 22 for heating, and flows the inside of a cooling pipe 23. As a cooling medium, gases, such as the compressed air and helium, or water is used. Based on the temperature of the substrate electrode holder 2 measured with the thermocouple 21, with the heat regulator which is not illustrated, the supply voltage to a heater 22, the temperature of the cooling medium in a cooling pipe 23, and the amount of supply can be adjusted, and it can be set as the substrate temperature made into the purpose.

[0020] The potential controlling mechanism 30 for controlling the potential of a substrate is formed in the substrate electrode holder 2. An insulator 31 is between the substrate electrode holder 2 and the processing room 3, and both are insulated electrically. High-frequency power is impressed to the substrate electrode holder 2 from RF generator 33 through a capacitor 32. For example, a RF with a frequency of 13.562MHz is adjusted to power 1500W, and it is impressed by the substrate electrode holder 2. A capacitor 32 adjusts the impedance at the time of RF impression. Although such a capacitor 32 will be inevitably formed if T mold circuit generally known as a matching circuit is used, this capacitor 32 plays the role by which the self-bias (bias component of a direct current) of the substrate 1 produced by impression of high-frequency power is made not to be grounded. Generally this self-bias is a negative dc component, and what has positive charge among the active species which exist in the processing room 3 is accelerated by this toward a substrate 1. Moreover, a frequency becomes it is also possible to use the RF generator of kHz order, and possible [being able to make positive charge exercise not only by the self-bias component but by RF electric field, and choosing the exposure of active species as arbitration] in this case. Furthermore, DC power supply or a 50-60Hz commercial frequency power source can also be used instead of RF generator 33. In this case, a capacitor 32 will be removed.

[0021] Next, the exhaustor style 40 is explained. The gas in the processing room 3 is exhausted by the turbomolecular pump 42 through a main valve 41. An oil sealed rotary pump 43 is for performing differential pumping of a turbomolecular pump 42. When the pressure in the processing room 3 needs to be controlled to a precision, it is effective if a variable conductance bulb (not shown) is installed between a main valve 41 and a turbomolecular pump 42. By changing the conductance of a variable conductance bulb based on the signal from a manometer (not shown) formed in the processing room 3, the pressure in the processing room 3 can be kept constant. Moreover, like [at the time of substrate exchange], in order to exhaust the processing room 3 from an atmospheric pressure to the pressure (about 1 Torr) of a turbomolecular pump 42 which can be operated, the

skimming exhaust air system which is not illustrated is required. It is effective in a skimming exhaust air system to use together a Roots pump and an oil sealed rotary pump.

[0022] Next, the elevated-temperature nonequilibrium plasma developmental mechanics 50 is explained. A plasma generating room is formed with the discharge tube 51 made from quartz glass (SiO_2). This discharge tube 51 is used as double tubing of quartz glass, poured water and has cooled in the meantime. This has prevented the dissolution of the discharge tube 51 by plasma heating. In addition, although the etching rate of the quartz glass by the fluorine radical increases and the damage of quartz glass becomes large so that the temperature of the discharge tube 51 becomes high when a fluorine radical is in the plasma generating interior of a room, the above-mentioned cooling means is effective also in preventing this.

[0023] The coiled form antenna 52 is arranged around the discharge tube 51. The alternation power emitted from RF generator 53 is impressed to an antenna 52 through the matching circuit which is not illustrated. If a gas is introduced into a plasma generating room and above-mentioned alternation power, the bore of the discharge tube 51, etc. satisfy predetermined conditions, the elevated-temperature nonequilibrium plasma 60 will occur. A switch 54 chooses the direction of the touch-down of an antenna 52. In addition, it is good also considering the both ends of an antenna 52 as floating potential, or good also as a configuration which grounds upper limit or a lower limit.

[0024] The production approach and equipment configuration of the elevated-temperature nonequilibrium plasma 60 are indicated in detail by JP,4-71575,B by application of an applicant for this patent, JP,62-227089,A, and JP,63-166971,A. In addition, vocabulary called the LTE plasma indicated by the official report of these three affairs has pointed out the same thing as the elevated-temperature nonequilibrium plasma in this application specification. On this application specifications, rather than the vocabulary the "LTE plasma", the direction of "elevated-temperature nonequilibrium plasma" depended reflecting the actual condition of the plasma, considered the suitable vocabulary, and has adopted this.

[0025] Next, a gas installation device is explained. This example is equipped with the 1st gas installation device 70 and the 2nd gas installation device 80. In the 1st gas installation device 70, the 1st gas passes along a pressure reducing pressure control valve from the gas bomb which is not illustrated, and control of flow of it is carried out by the flow controller, and it is introduced into the interior of the discharge tube 51 from the direction of an arrow head 72 through a bulb 71. The elevated-temperature nonequilibrium plasma 60 is activated, the high-concentration active species 4 produces this 1st gas by this, and neutral active species is mainly used for the target surface treatment among this active species.

[0026] In the 2nd gas installation device 80, the 2nd gas passes along a pressure reducing pressure control valve from the gas bomb which is not illustrated, and control of flow of it is carried out by the flow controller, and it is introduced in the processing room 3 from the direction of an arrow head 82 through a bulb 81. The 2nd gas lets the stoma 84 of a large number prepared in the gas blowdown ring 83 of an anchor ring pass, and is introduced into the interior of the processing room 3.

[0027] Only with the 2nd gas, if an argon etc. is used as the 1st gas when the elevated-temperature nonequilibrium plasma 60 becomes unstable, it will become possible to stabilize the elevated-temperature nonequilibrium plasma 60, and good surface treatment will become possible [with a sufficient controllability].

[0028] Next, the multi-cusp field developmental mechanics 90 is explained. Drawing 2 (A) is the A-A line sectional view of drawing 1. The multi-cusp field 93 is formed in the perimeter of the outer wall of the processing room 3 by arranging many magnets 91. Each magnet 91 is prolonged for a long time in the vertical direction (refer to drawing 1), and the Rhine-like multi-cusp field 93 is formed in the interior of a processing room. As for a magnet 91, it is desirable to make powerful magnets, such as a samarium cobalt magnet, small, and to arrange them densely. If the pole face of the processing room 3 and the opposite side is fixed to Pau ****. ** 92 produced with ferritic stainless steel and it carries out like this, a magnetic field can be generated more effectively.

[0029] Drawing 2 (B) is the flat-surface sectional view which expanded near the wall surface of a processing room. The internal surface of the processing room 3 is covered by the neutral active species reflective member 94. This neutral active species reflective member 94 does not exist near [spinode 95] a multi-cusp field, but is installed only in the location distant from spinode 95. In this example, the neutral active species reflective member 94 is formed with poly tetrafluoroethylene. Coating of this neutral active species reflective member 94 is carried out to the internal surface of the processing room 3. The plasma in the processing room 3 is shut up near the center of the processing room 3 by existence of the multi-cusp field 93, and the plasma does not touch the neutral active species reflective member 94 with it by it. Moreover, although the plasma can approach a wall surface in the spinode 95 neighborhood, since the neutral active species reflective member 94 does not exist in this part, the neutral active

species reflective member 94 is not too exposed to the plasma. Therefore, the neutral active species reflective member 94 does not receive a damage, or the matter inconvenient to substrate processing does not disperse in the processing interior of a room. Although it will collide with the neutral active species reflective member 94, without confining neutral active species in the multi-cusp field 93, neutral active species can return to the interior of a processing room, reflecting by the neutral active species reflective member 94, and maintaining an active state. When the neutral active species reflective member 94 does not exist, neutral active species will collide with the internal surface of stainless steel, and the activity will be lost.

[0030] In addition, in the example of drawing 2 (A), although the pole piece 92 is formed annularly, by the example of drawing 2 (B), pole piece 92b is divided so that only the magnet 91 of an adjacent pair may be connected. If it carries out like the latter, since the outer wall of the processing room 3 can be approached from between pole piece 92b, a view port and various kinds of ports can be installed between magnets 91.

[0031] Next, the example which applied the equipment shown in drawing 1 and drawing 2 to the actual surface treatment process is shown. In drawing 1, oxygen gas is passed by the flow rate of 200sccm(s) through the 1st gas installation device 70. Moreover, silane gas is passed by the flow rate of 100sccm(s) through the 2nd gas installation device 80. The pressure in the processing room 3 is maintained at 8×10^{-3} Torr. Alternation power (13.560MHz and 2kW) is outputted from RF generator 53, and the interior of the discharge tube 51 is made to generate the elevated-temperature nonequilibrium plasma 60. Moreover, the alternation power of 13.562MHz and 1500W is outputted from RF generator 33, and bias voltage is impressed to the substrate electrode holder 2. A substrate 1 carries out heating maintenance through the substrate electrode holder 2 at 150 degrees C. SiO₂ film was deposited on the large area silicon wafer with a diameter of 10 inches using such conditions. The thickness distribution became 2micrometer**3%, and was very good. [of the homogeneity of thickness]

[0032] By the time this SiO₂ film accumulates on a substrate, the following phenomena will have arisen. The elevated-temperature nonequilibrium plasma 60 is activated and a lot of oxygen atoms (neutral active species) produce the oxygen gas introduced from the 1st gas installation device 70. On the other hand, the plasma of the processing interior of a room decomposes, and silane gas (SiH₄) serves as SiH₃. An above-mentioned oxygen atom borrows the assistance of the heat energy from breadth and the heated substrate 1 in the processing interior of a room, and reacts with SiH₃, and SiO₂ film deposits it on a substrate 1. Since the pressure in the processing room 3 is as low as 2×10^{-2} - 5×10^{-4} Torr, it will reach near the internal surface of a processing room frequently, without the mean free path being comparatively long, and an oxygen atom colliding with other particles not much. If an oxygen atom collides with the neutral active species reflective member 94 (refer to drawing 2 (B)), it reflects with an oxygen atom (namely, have maintained the active state), and the most returns to the processing indoor section.

[0033] If the neutral active species reflective member 94 does not exist, it will collide with the internal surface of the processing room made from stainless steel directly, will combine with a wall surface metal temporarily, and an oxygen atom will become an oxide. If an oxygen atom collides with this part further, it will react with the oxygen atom combined with the metal, and an oxygen molecule will be made. Even if this oxygen molecule returns to the processing interior of a room, it will not contribute to a film deposition reaction and will only be exhausted.

[0034] after all, according to this example, it could contribute to the film deposition reaction, without being lost vainly in the processing interior of a room, and also in the low pressure, even if a mean free path was comparatively long and neutral active species tended to have collided with a wall surface namely,, the high-speed film deposition processing of a lot of oxygen atoms generated by elevated-temperature nonequilibrium plasma was attained.

[0035] In this example, the potential controlling mechanism 30 is useful to raising the step coverage of SiO₂ film. Although the oxygen atom has contributed to the reaction as mentioned above, the deposition of SiO₂ film itself can carry out the impact of the film with the cation of the processing interior of a room, if the potential controlling mechanism 30 is used. Thereby, the covering nature of SiO₂ film can be raised in the level difference section side face of the pattern currently beforehand produced on the silicon wafer. To this cation, the plasma confinement operation by the multi-cusp field will work, and the effectiveness of the impact operation by the cation will arise in homogeneity over a large area. When not using the potential controlling mechanism 30, a step coverage property will be inferior. When the potential controlling mechanism 30 was used, the front face became flat by depositing SiO₂ film by the thickness of about 2 micrometers on the level difference of 1 micrometer which existed beforehand on the wafer. This technique is important especially for the production technique of the multilayer interconnection used with the increment in the degree of integration of a semi-conductor, or the exposure technique (the depth of field needed in the case of exposure is shallow.) of a detailed pattern.

[0036] By the way, when both oxygen and silane are introduced from the 1st gas installation device 70, a reaction

mainly progresses in the interior of the elevated-temperature nonequilibrium plasma 60, and its near, consequently the homogeneity of substrate processing worsens, and there is a fault that a deployment of material gas cannot be performed, either. On the other hand, when both oxygen and silane are introduced from the 2nd gas installation device 80, only the oxygen diffused in the discharge tube 51 will be activated by elevated-temperature nonequilibrium plasma, the activation effectiveness of oxygen decreases, and there is a fault which cannot perform a deployment of material gas too. Therefore, SiO₂ To membranous deposition, it was very useful to have used together the 1st gas installation device 70 and the 2nd gas installation device 80 as mentioned above.

[0037] Moreover, in the above-mentioned film production conditions, if nitrous oxide gas (N₂O) is introduced instead of oxygen gas from the 1st gas installation device 70, nitrogen can produce SiO₂ film (it may be called the SiON film) which carried out little mixing. Furthermore, instead of oxygen gas, if ammonia gas or the ammonia gas of nitrogen dilution is used, an SiN film is producible. This SiN film can be used as the object for the passivation of a semiconductor device, or an object for the gate dielectric film of TFT (thin film transistor). In the case of this SiN film, if the potential controlling mechanism 30 is used, it is possible to control not only a step coverage but the stress of the deposition film.

[0038] Furthermore, only by introducing oxygen gas from the 1st gas installation device 70, when not using the 2nd gas installation device 80, it can use for ashing of a photoresist, the cleaning for organic substance removal, or scaling of the substrate quality of the material. For example, in ashing of a photoresist, or the cleaning for removal of the organic substance, when temperature of a substrate was made into about 120 degrees C, it has processed effectively. In this case, as for the flow rate of oxygen, the direction of effectiveness of a large quantity was size from 100sccm(s). Also in this case, in the silicon wafer with a diameter of 10 inches, homogeneous good processing was possible.

[0039] As processing which oxidizes the substrate quality of the material, it is effective in production of metal oxide films, such as production of an oxide superconductor, a tantalum, titanium, a ruthenium, iridium, a tungsten, and aluminum, oxide-film production of silicon, etc. The oxide film of a tantalum can be used as a dielectric film for capacitors of a semiconductor device. Titanium can be used as ion conductivity film and the oxide of a ruthenium, iridium, and a tungsten can be used as a titanium-dioxide semiconductor electrode as the object for the sensing matter thin films of various sensors, or a thin film for clo MIZUMU. Aluminum oxide can be used as an insulator thin film of various devices. The thickness of the oxidizing zone of these oxidation treatments was settled in $\pm 3\%$ of distribution in the field with a diameter of 10 inches, and was able to acquire very good homogeneity.

[0040] Drawing 3 is the transverse-plane sectional view of the 2nd example of this invention. Multi-cusp field developmental mechanics differs and other parts are the same as the example shown in drawing 1. Therefore, the same sign is attached to the same part as the example of drawing 1. Multi-cusp field developmental mechanics 90a of this example forms the ring-like multi-cusp field by arranging a magnetic pole by turns in the vertical direction on the outside of that side attachment wall. Moreover, the magnet is arranged also to processing room 3 a top and the bottom. Each magnet 91a was made smaller than the magnet shown in drawing 1, and is arranged densely. Although trouble starts manufacture of multi-cusp field developmental mechanics compared with the example of drawing 1, the use effectiveness of the active species in the processing interior of a room can be raised in this example.

[0041] Drawing 4 is the transverse-plane sectional view of the 3rd example of this invention. It differs from the example shown in drawing 1 in that the magnetic field developmental mechanics for discharge was prepared in the perimeter of the discharge tube 51, and other parts are the same. Therefore, the same sign is attached to the same part as the example of drawing 1. In this example, the magnetic field developmental mechanics which consists of an electromagnet 55 is prepared in the perimeter of the antenna 52 of the outside of the discharge tube 51. Thereby, inside the discharge tube 51, a magnetic field is formed in the vertical direction. If the interior of the discharge tube 51 is made to generate a magnetic field, generating and its maintenance of the elevated-temperature nonequilibrium plasma 60 in the low voltage force will become easy.

[0042] Drawing 5 is the transverse-plane sectional view of the 4th example of this invention. This example combines the magnetic field developmental mechanics for discharge shown in the equipment shown in drawing 3 at drawing 4, and improves the configuration of antenna 52a around the discharge tube 51 further. The configuration of this antenna 52a is shown in drawing 6 (A). This antenna 52a is the configuration which opens two rings in the vertical direction and has arranged spacing instead of a coiled form as shown in drawing 1. However, these rings are continuing with one conductor. If the antenna of this configuration is used, the elevated-temperature nonequilibrium plasma of higher ion density can be generated. Drawing 6 (B) is another example of the same

antenna, and the part of the root of antenna 52b has become coaxial cable 52c.

[0043] Drawing 7 is the transverse-plane sectional view of the 5th example of this invention. This example removes the 1st gas installation device 70 from the equipment of drawing 1. When it does in this way, although it is disadvantageous from the viewpoint of generating of active species as above-mentioned, from a viewpoint on equipment manufacture, there is an advantage from which processing and installation of the discharge tube 51 become easy.

[0044] Next, the combination of the class of neutral active species which contributes to plasma treatment, and the quality of the material of a neutral active species reflective member is described. The next table 1 shows the purpose of plasma treatment, the neutral active species which participates in the processing, and the quality of the material of the reflective member for reflecting the neutral active species effectively. Although the cable address has shown a part of quality of the material of a reflective member, the semantics is shown under a table.

[0045]

[Table 1]

The processing purpose Neutral active species Reflective member SiO₂ Deposition O atom SG, PG, AO, TFSiN deposition N atom SG, PG, AO, SiN etching F atom TF, AO etching Cl atom TF, SG, PG, AO diamond film deposition H atom AO-diamond[SiC, SiN, SG, PG, and]-like Carbon film deposition H atom SiC, SiN, SG, PG and AO, however SG -- Quartz glass PG -- Pyrex (trademark) glass AO--aluminum 2O₃ TF -- Poly tetrafluoroethylene

[0046] [Effect of the Invention] Since this invention separated the plasma of the processing interior of a room from the internal surface of a processing room by the multi-cusp field while generating a lot of neutral active species using elevated-temperature nonequilibrium plasma, it becomes possible to cover the internal surface of a processing room by the neutral active species reflective member, and it can prevent a useless reduction of neutral active species. Consequently, good substrate processing was attained at the large area covering a high speed and homogeneity.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is the transverse-plane sectional view of the 1st example of this invention.

[Drawing 2] They are the A-A line sectional view of drawing 1, and an expansion horizontal sectional view near the processing interior wall side.

[Drawing 3] It is the transverse-plane sectional view of the 2nd example of this invention.

[Drawing 4] It is the transverse-plane sectional view of the 3rd example of this invention.

[Drawing 5] It is the transverse-plane sectional view of the 4th example of this invention.

[Drawing 6] It is the perspective view showing the configuration of the antenna of the example shown in drawing 5.

[Drawing 7] It is the transverse-plane sectional view of the 5th example of this invention.

[Description of Notations]

1 -- Substrate

2 -- Substrate electrode holder

3 -- Processing room

4 -- Active species

20 -- Temperature-control device

30 -- Potential controlling mechanism

40 -- Exhauster style

50 -- Elevated-temperature nonequilibrium plasma developmental mechanics

60 -- Elevated-temperature nonequilibrium plasma

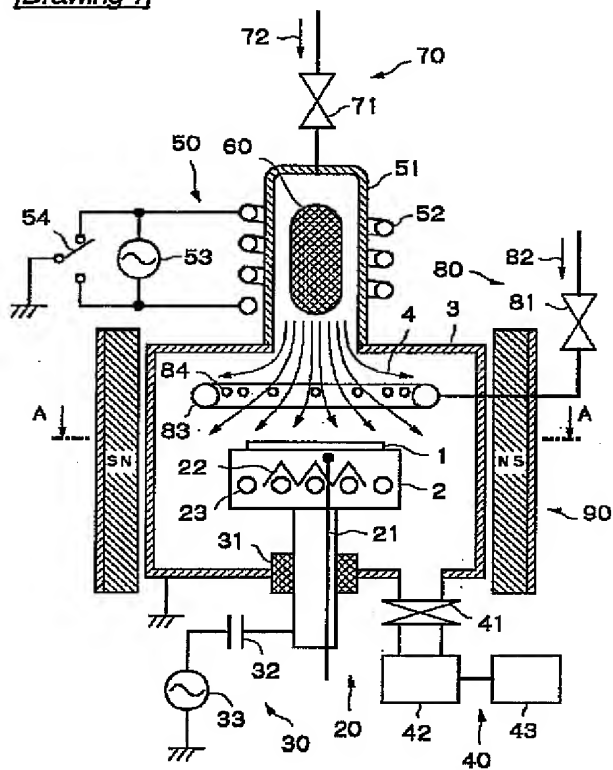
70 -- 1st gas installation device

80 -- 2nd gas installation device

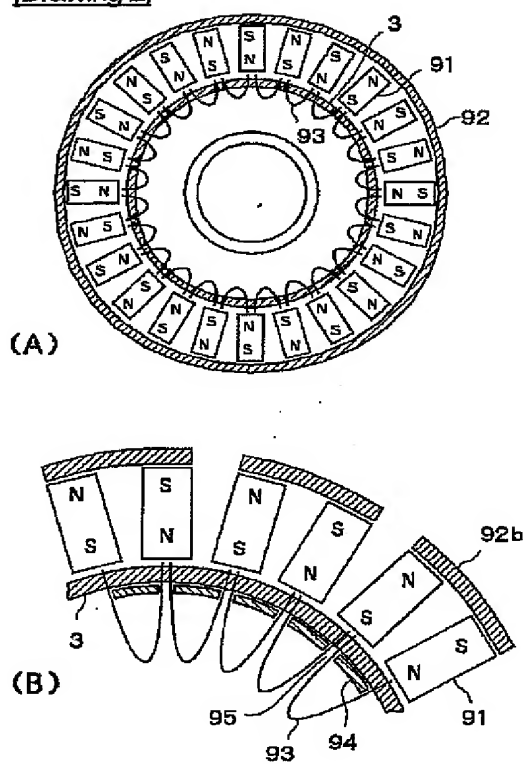
90 -- Multi-cusp field developmental mechanics

DRAWINGS

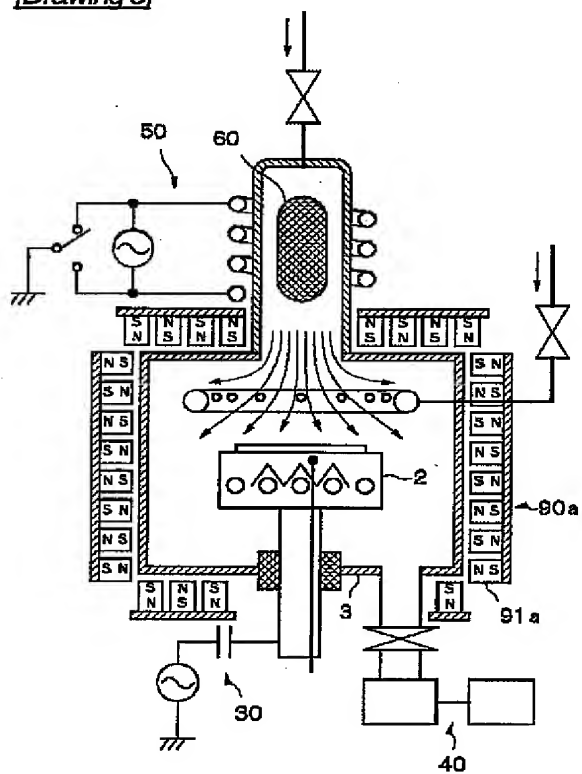
[Drawing 1]



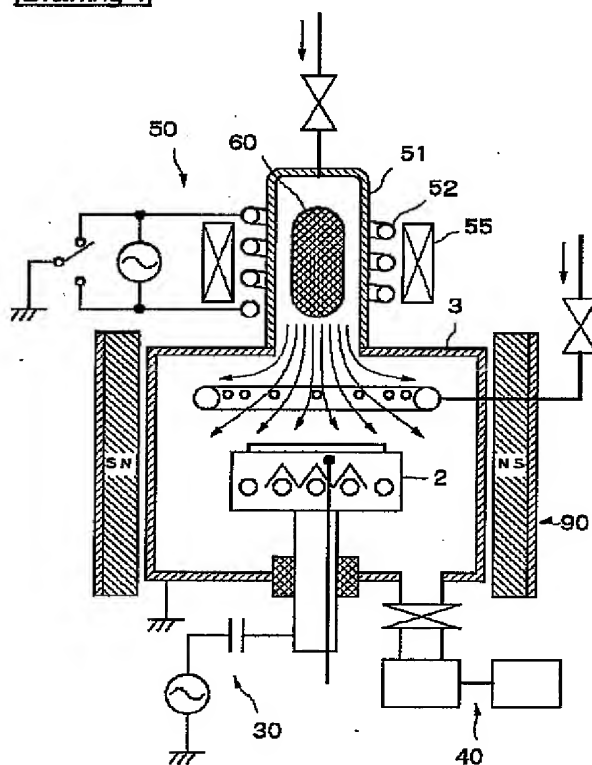
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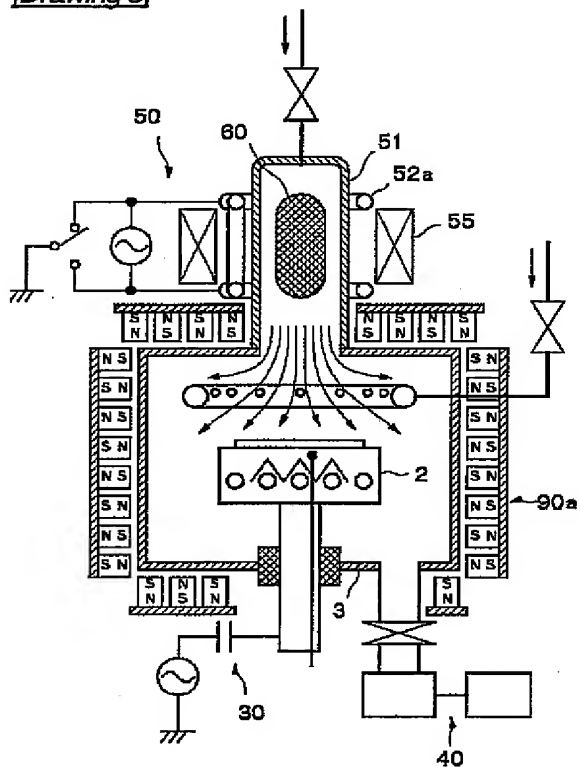
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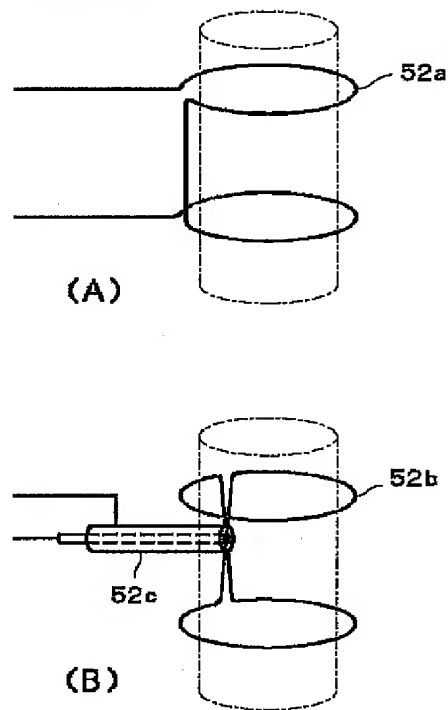
[Drawing 4]



[Drawing 5]



[Drawing 6]



[Drawing 7]

